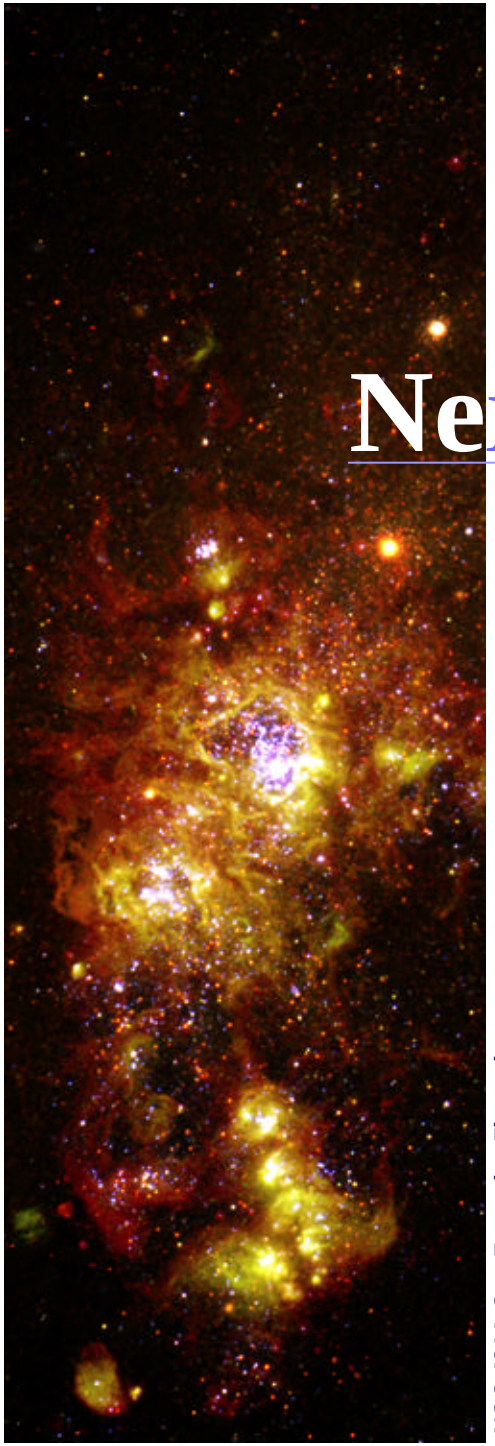


NGC 4214 Star Formation Fireworks

Next Generation Space Telescope (NGST)

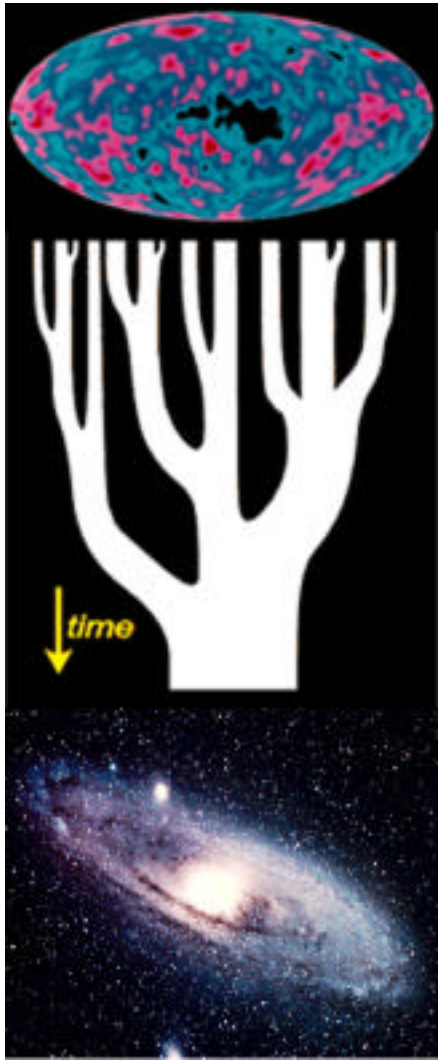
Presented by

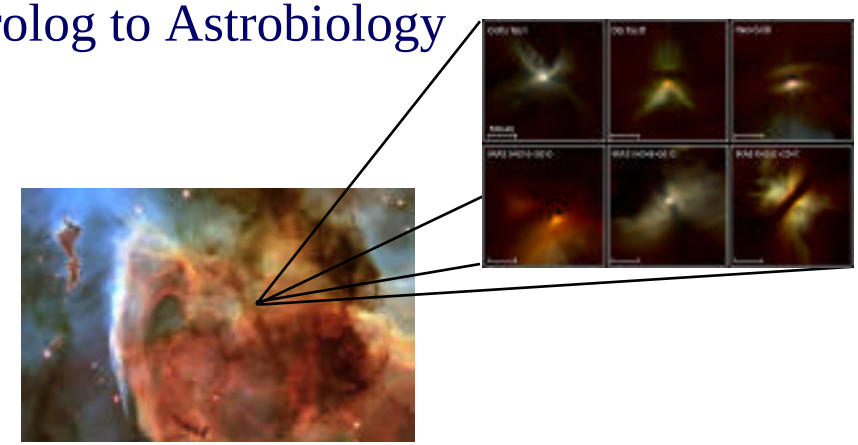
Eric Smith

Deputy Project Scientist

Key NGST Science Objectives

- Detect and Characterize the First Stars and Galaxies to Form after the Big Bang
  - "First Light" Machine
- Measure the Complete Formation Processes of Galaxies and the Creation of Heavy Elements
  - Visiting a Time When Galaxies Were Young
- Study the Details of Star and Planet Formation in our Galaxy
  - Prolog to Astrobiology





Next Generation Space Telescope

NGST

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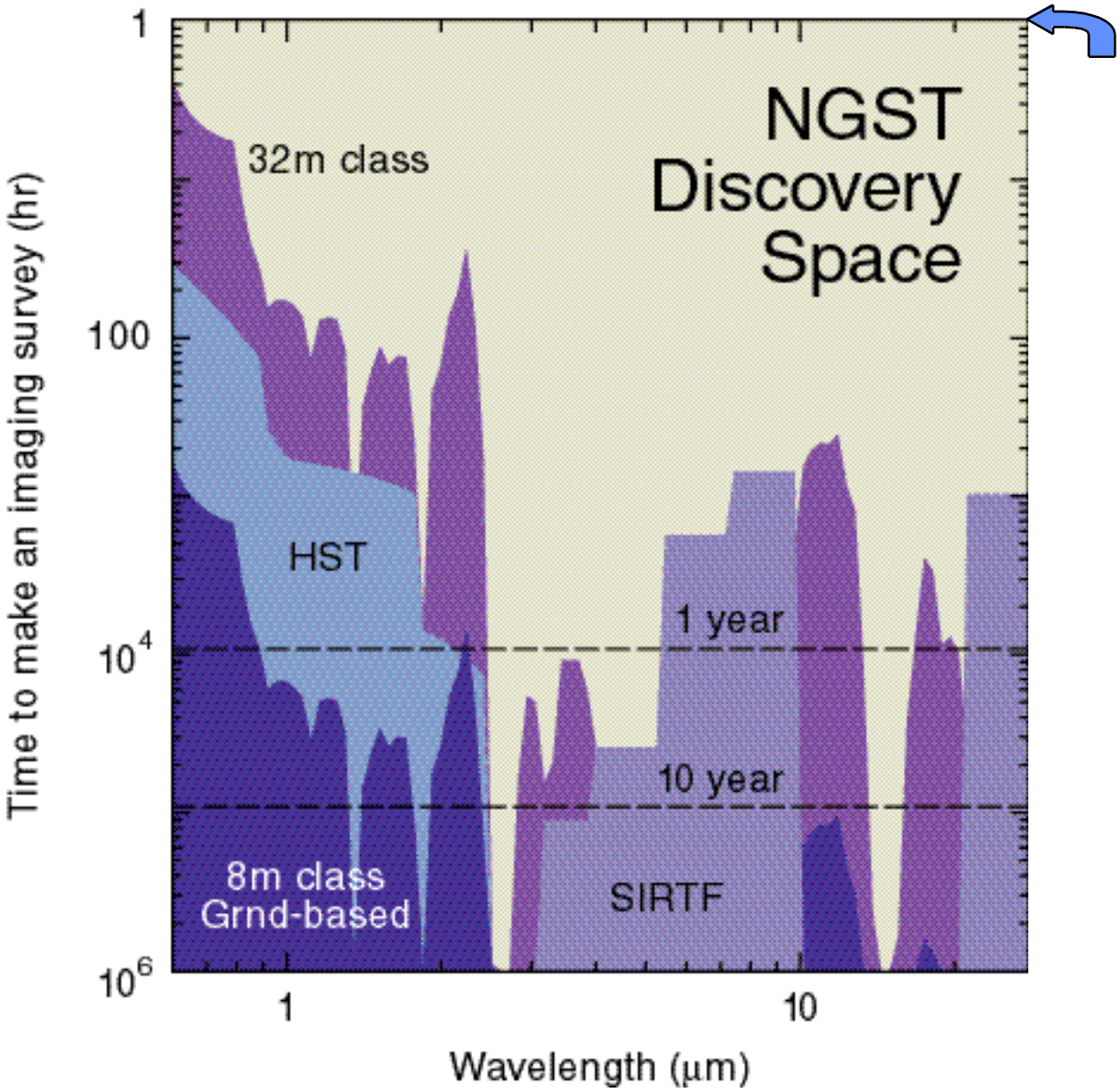
Discovery Space for NGST



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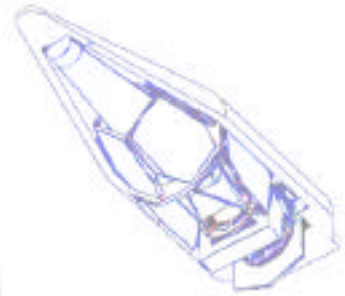
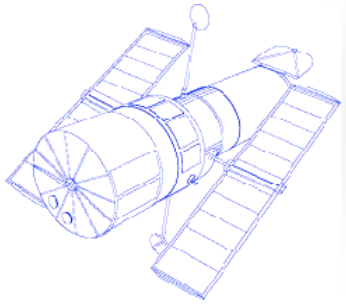
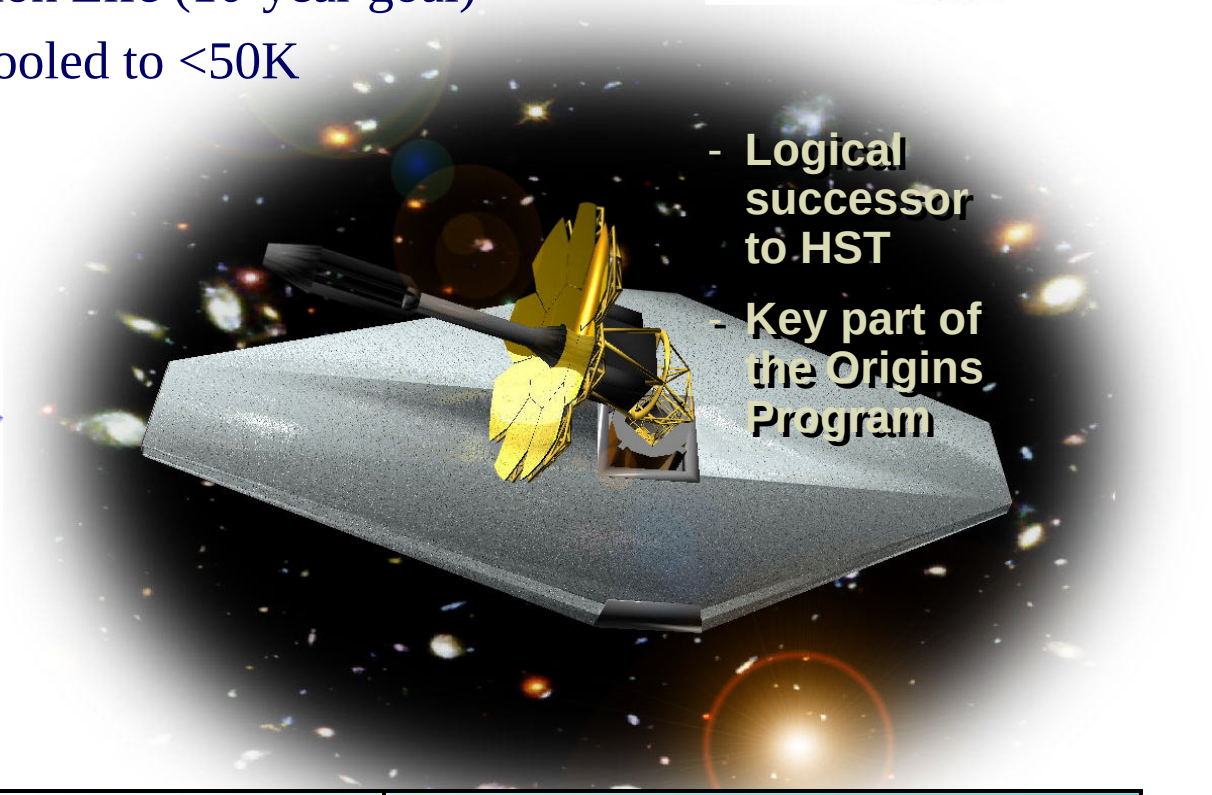
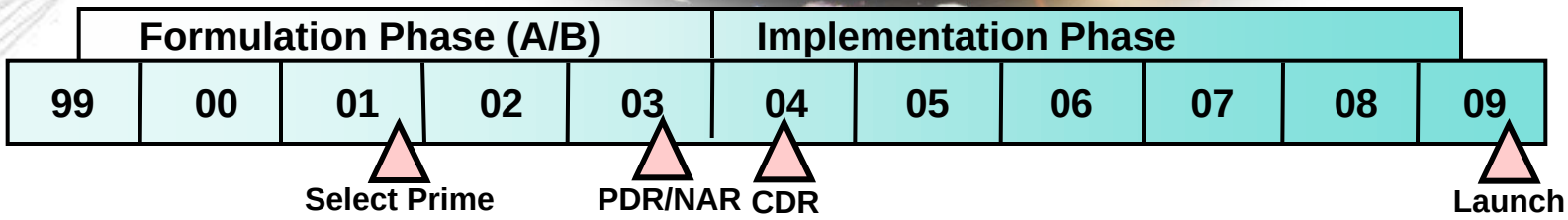
NGST at a Glance

- 8m Primary Mirror
- 0.6-10+ µm Wavelength Range
- 5 year Mission Life (10-year goal)
- Passively Cooled to <50K
- L2 Orbit









NGST
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Quantifying Science Goals: The DRM

- The Design Reference Mission (DRM) was created by the Ad hoc Science Working Group
- DRM contains the "Dressler Report" science
- DRM does not preempt proposal process
- Comprised of 23 large, critical science programs that could be carried out in ~2.5 years
- 7 Core Programs
  1: Formation & Evolution of Galaxies – Imaging
  2: Formation & Evolution of Galaxies – Spectroscopy
  3: Mapping Dark Matter
  4: Search for Reionization Epoch
  5: Measuring Cosmological Parameters
  6: Formation & Evolution of Galaxies – Obscured Stars & AGN
  7: Physics of Star Formation: Protostars

Next Generation Space Telescope
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Science Goals Drive Observatory Performance

1: 2 μm Diffraction Limited Imaging, Large FOV, 8m Sensitivity, 0.6-5 μm

2: 1-5 μm NIR Multiplexed Spectroscopy, *R*=100-3000; 5-10 μm Spectroscopy, *R*=3000

3: Very Wide FOV; Stable Point-Spread Function

4: Very Sensitive NIR Spectroscopy, *R*=100-300

5: Ability to follow fields over months

6: MIR (10-28+ μm) Imaging/Spectroscopy, *R*=300

7: MIR (10-28+ μm) Imaging/Spectroscopy, *R*=3000+

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Recommended Instruments for NGST Goals

- 4´ x 4´ NIR Camera (8k x 8k pixels)
  - Nyquist sampled at 2 µm, 0.6-5 µm, *R*~100 grism mode
    - First light, galaxy formation, dark matter, supernovae, young stars, Kuiper Belt Objects (KBO), stellar populations **(1, 3, 5, 6)**
- 3´ x 3´ NIR *R*~1000 Multi-Object Spectrograph
  - Simultaneous source spectra(≥ 100), 1-5 µm
    - Gal formation/diagnostics (clustering, abun., star form., kinematics), Active Galactic Nuclei, young stellar clusters (Initial Mass Function (IMF)/stellar populations) **(2, 4, 5, 7)**
- 2´ x 2´ Mid IR Camera/*R*~1500 Spectrograph
  - Nyquist sampled at ~10 µm, 5-28 µm, grisms & slit
    - Physics of old stars at high redshift, z~5 obscured star form. & Active Galactic Nuclei to *z* ~ 5, PAHs to *z*~5, Ha to z~15 , cool stellar IMF, protostars and disks, KBO sizes, comets **(1, 6, 7)**

(Core science program numbers in **red**)

Next Generation Space Telescope
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Desirable 4th Instrument Capabilities

- NIR *R*=3000-5000 PSF-sampled spectrograph
  - ≤0.1´´ angular resolution, ~2´´ x 2´´ FOV
  - 2d for single, extended object spectroscopy
- 0.6 - 1 μm camera (sampling diffraction spike)
  - ~0.01´´ angular resolution, 1´ x 1´ FOV
  - (Note-- assumes NIRCAM has 0.6 μm capability)
  - Stellar pops/White Dwarf cooling curve, circumstellar disks, high-*z* gal. Morphology
- MIR *R*=3000-5000 PSF-sampled spectrograph
  - ≤0.3´´ angular resolution, ≥ 2´´ x 2´´ FOV, 5-28.3 μm
  - Instead of *R*~1500 add-on spectrograph to MIR camera

Next Generation Space Telescope
NGST
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NGST Key Technologies

- Technologies must be sufficiently mature by Non-Advocate Review (Technology Readiness Level – TRL 6)
- The following have been identified as key technologies:

Technology Product	Affected Science Programs	TRL Level	$(M)	% Technology Budget
Lightweight Cryogenic Primary Mirror	1-7	**3-4**	**29.0**	**37%**
Large Format, Low Noise IR detectors	1-7	**4**	**15.0**	**19%**
Wavefront Sensing & Control Methodology	1-7	**4**	**11.4**	**15%**
MEMS Spectroscopic Slit Assemblies	2	**3-4**	**11.2**	**14%**
Low Vibration, Long Life Cryo-coolers	6, 7	**4**	**5.0**	**6%**
Lightweight Sunshield	1-7	**3**	**3.8**	**5%**
Cryogenic Actuators	1-7	**4-5**	**0.9**	**1%**
Cryogenic Deformable Mirror	1, 3, 5	**2-3**	**0.9**	**1%**
Precision Deployable Structures	1-7	**4-5**	**0.5**	**<1%**
Vibration Control Methodology	1-7	**5-6**	**0.5**	**<1%**

Items in ***red*** are critical path technologies that strongly influenced decision to replan schedule

Next Generation Space Telescope
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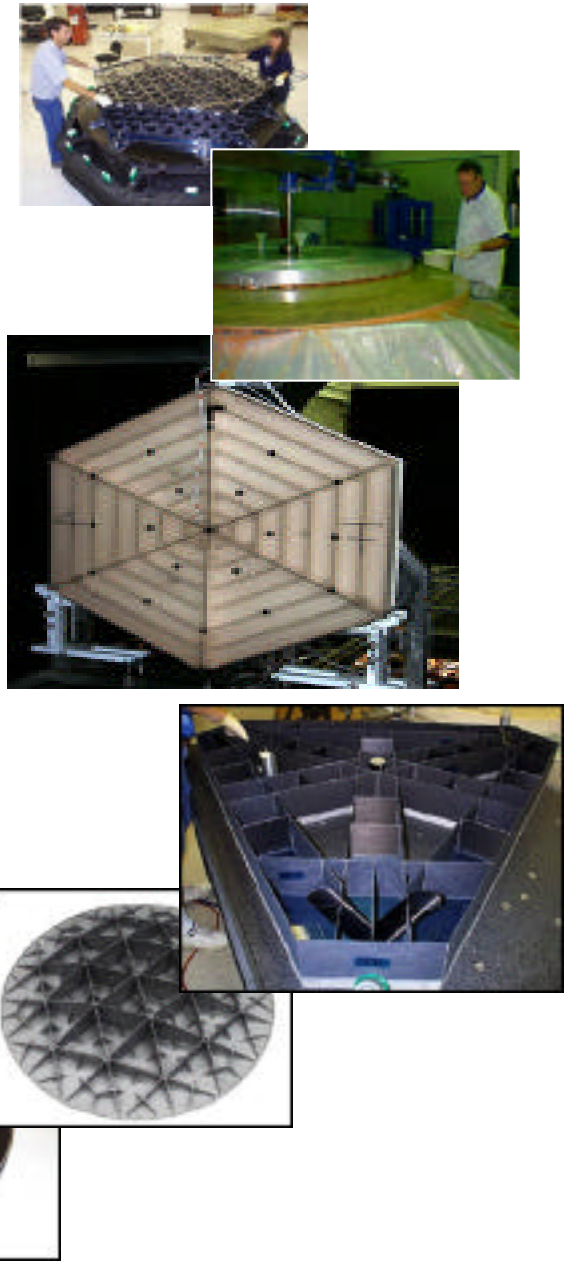
Lightweight Cryogenic Optics (TRL 3-4)

- Objective/Requirements
  - 8m deployable primary, <15 kg/m^2 areal density, 2µm diffraction limit, T<40K
- Technology Development Efforts
  - NGST Mirror System Demonstrator (NMSD)
    - COI/REOSC (1.5m glass/composite)
    - University of Arizona (2m glass shell/composite)
  - Subscale Demonstrators
    - Ball/Tinsley (0.5m beryllium)
    - IABG (0.5m C-SiC)
  - Advanced Mirror System Demonstrator (AMSD)
    - Phase 1 Contracts completed
      - Raytheon, Kodak, Ball, COI, U. of Arizona
    - Phase 2 Contractors selected
  - Test facility ready at MSFC
- TPF also investing in AMSD
- Issues
  - To date progress slower than anticipated
    - Launch deferred



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IR Detectors & Focal Plane Arrays (TRL 4)

- Objective: Develop & demonstrate very **large format** IR arrays, with sensitivity for **background-limited** observations

Sensitivity Challenges

Near-IR: Low Noise, 90% QE
<0.02e/sec dark current
<15 e/sec read noise
Pursuing **InSb** and 5μm **HgCdTe**

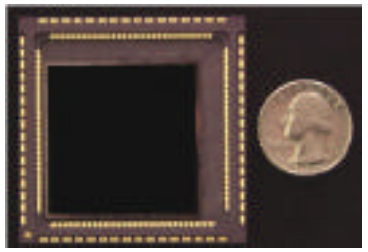
Mid-IR: Low Noise, 80% QE
<1e/sec dark current
<15 e/sec read noise
Pursuing **Si:As**, Si:Ga, & 10μm HgCdTe

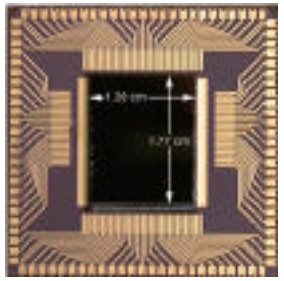
Size, Producibility Challenges

Chip Format: Develop 1KX1K & 2KX2K
Tiling Chips: make 16Mpixel FPAs
Manufacturing: yield, low-cost, high-volume

2 k x 2 k muxes

2 k x 2 k HgCdTe FPA





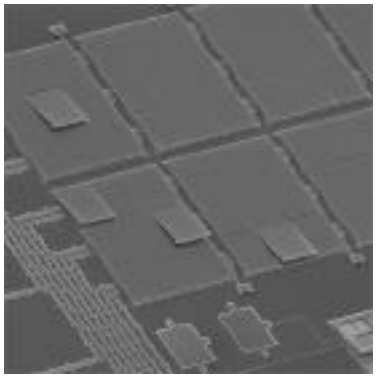
412x512
Si:As array

4 k x 4 k working mockup

Well-characterized technology options for instrument proposals in 2002/3

Micromirror Test Arrays for NGST (TRL 3-4)

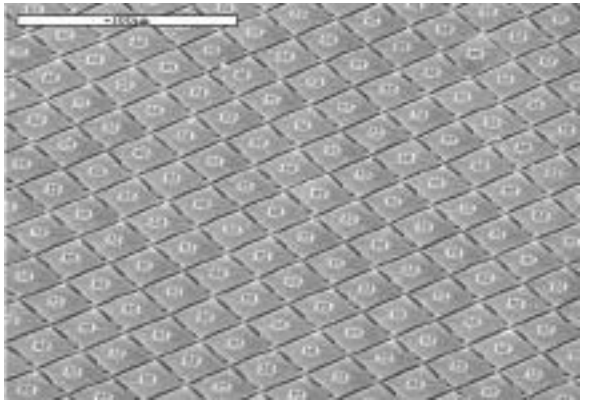
- Objective:Develop technology to allow selection of >100 targets per/FOV for spectroscopy
- Affected Science Programs **(2, 4, 6)**
- Pursuing both micromirror and microslit selector technologies
- Major focus for NRA 2 funding



Sandia National Lab.

(Both designs feature 100 µm mirror elements)

- Issue: Riskiest instrument technology, offramps to be pursued in NRA 2 also



GSFC 256x256 array

Next Generation Space Telescope

NGST

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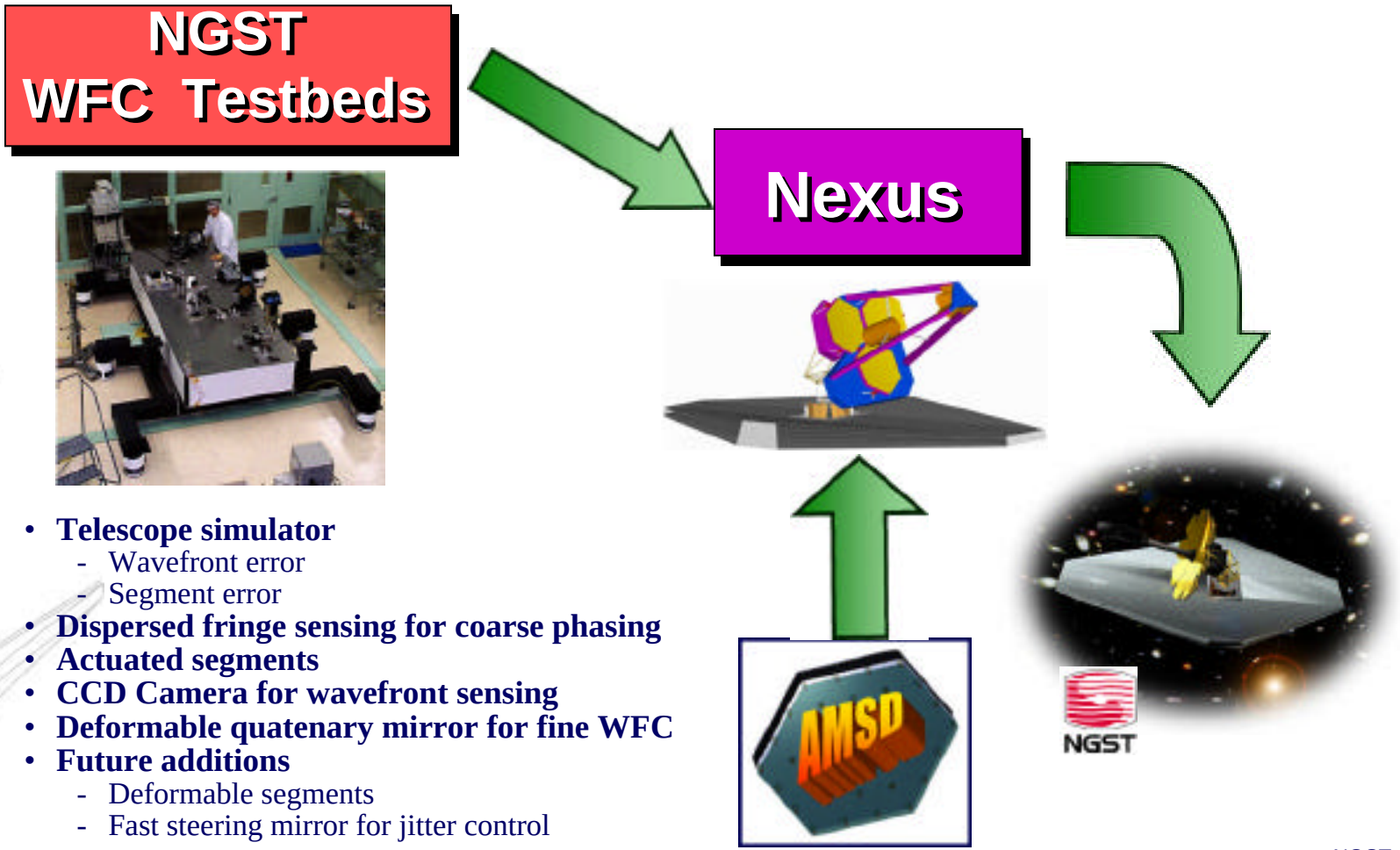
Wavefront Sensing & Control (TRL 4)

- Objective: develop models and algorithms for controlling segmented optics on testbeds for use in Nexus and ultimately NGST
- Affected Science Programs **(1-7)**



- **Telescope simulator**
  - Wavefront error
  - Segment error
- **Dispersed fringe sensing for coarse phasing**
- **Actuated segments**
- **CCD Camera for wavefront sensing**
- **Deformable quatenary mirror for fine WFC**
- **Future additions**
  - Deformable segments
  - Fast steering mirror for jitter control

Next Generation Space Telescope
NGST
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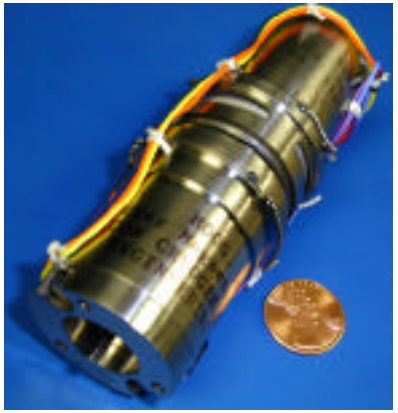
NGST Cryogenic Actuators (TRL 4-5)

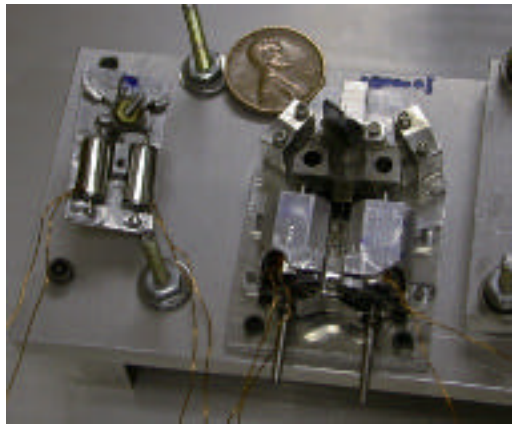
- Objective: Produce actuators to adjust Primary Mirror shape and segment phase
- Affected Science Programs **(1-7)**

Critical Requirements:
- **30K operation**
- **20nm resolution**
- **6mm stroke**



Al Hatheway-developed Actuator
- **Cryo tested at JPL**
- **10mm stroke**
- **8nm resolution**
- **Electromagnetic stepper motor/gearbox design by Schaeffer**

Langley-developed Actuator
- **Being tested**
- **10mm stroke**
- **13nm resolution**
- **Weighs 58gm**
- **Uses a Smoothy motor/gearbox**

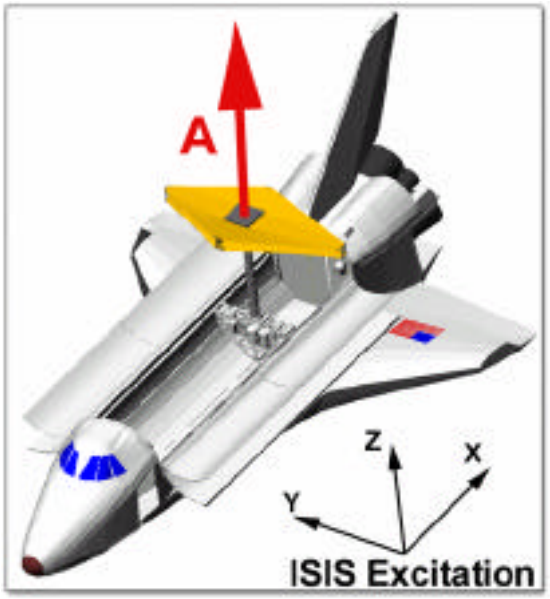


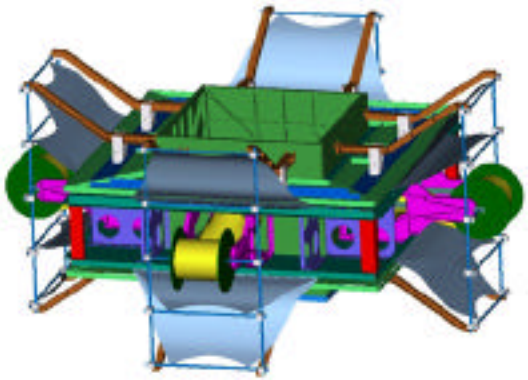
U/Az Impact-Driven Figure-Control Actuator

- Success
  - Technology Development by Govt. Concluded; Transferred to Industry

ISIS Sunshield Validation

- Validate key aspects of the deployment of a large, lightweight (gossamer) structure for NGST
  - Membrane handling
  - On-orbit dynamics and structural properties
  - Rigidization of struts
- Full scale thermal vac test at GSFC
- Scheduled launch: October, 2001
  - STS 112
  - 1/3rd scale
- May workshop with industry
- Issue
  - Assessing Feasibility of STS107 Launch (March 2001)





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How Nexus Benefits NGST

- It is the logical link between technology developments...

• AMSD cryo mirrors *• Deployment* *• Detectors*
• WFSC *• Sunshield* *• Industrial IR&D*

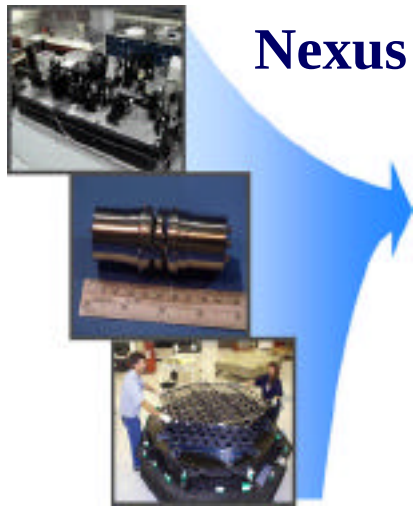
...government and industry system studies...

• Designs *• Metrology*
• Integration *•Operations*

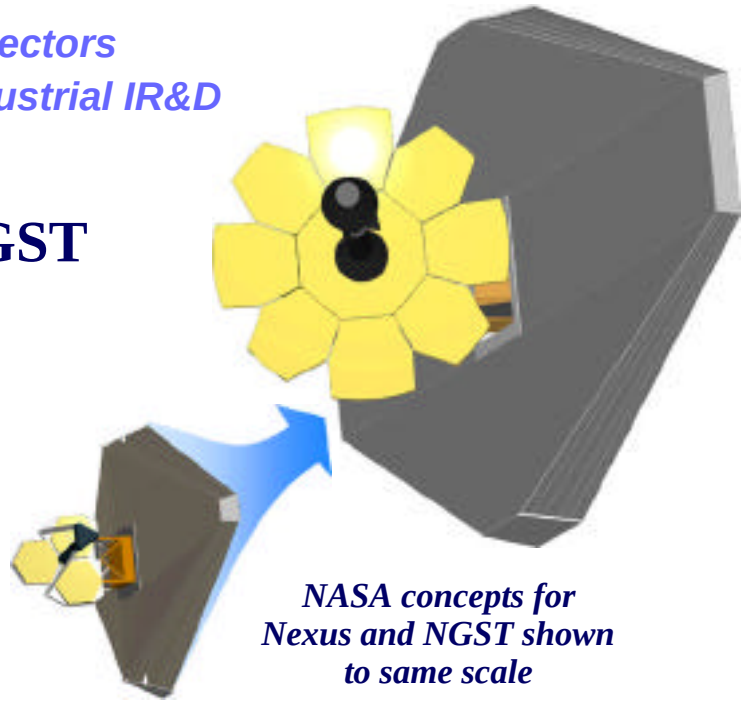
...management and process...

• Cost *• Schedule* *• Teaming*

...and the flight of NGST.



Nexus



NGST

NASA concepts for Nexus and NGST shown to same scale

In conjunction with OTA & Sunshield ground tests, it represents the lowest cost/risk systems verification approach for a large, ultra-lightweight telescope

Next Generation Space Telescope
NGST
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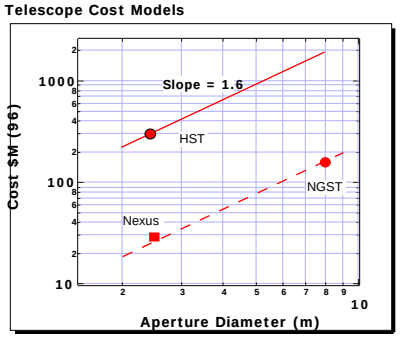
Nexus Mitigates NGST Cost & Risk

- Tests New Large Optics Cost Curve
- Operations & Algorithms
  - Observing efficiency ≥ 80%
    - Loss of 10% efficiency = loss of $50M in Observations
- I & T Methodology
  - Model Validation for Non-linear Effects in Zero-g Environment
  - Fabrication Techniques & Reduced Schedule
- Permits $-for-$ savings in NGST C/D costs by flying full-scale prototype hardware & software for NGST
  - Mirrors
  - Reaction structure
  - Actuators
  - Sunshield (1/2 scale)
  - NIRCAM SCA and C&DH
  - Wavefront Sensing and Control Algorithms
- Pathfinder to Normal Processes for Future Large Space Telescopes



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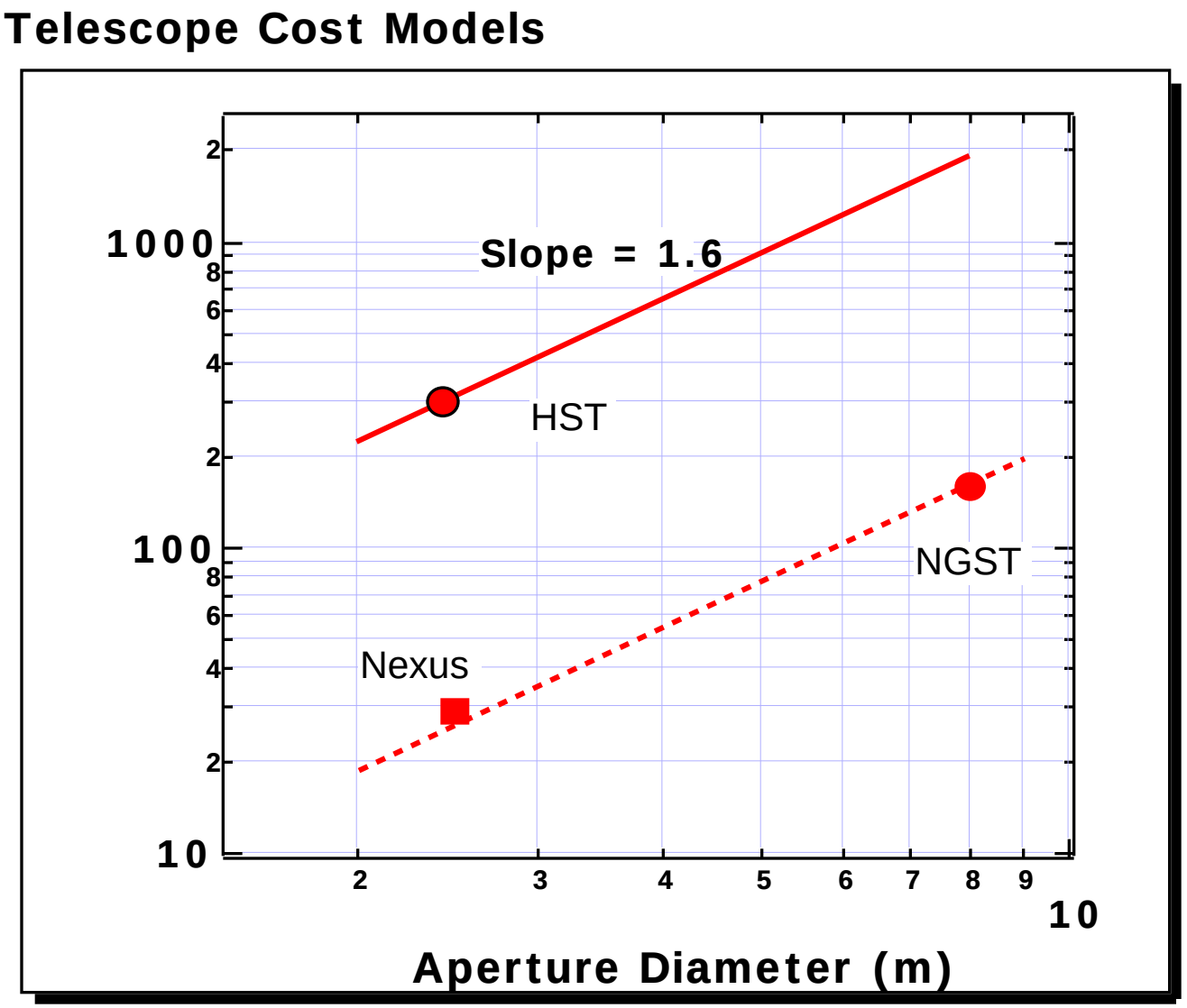
Nexus Mitigates NGST Cost & Risk (cont'd)



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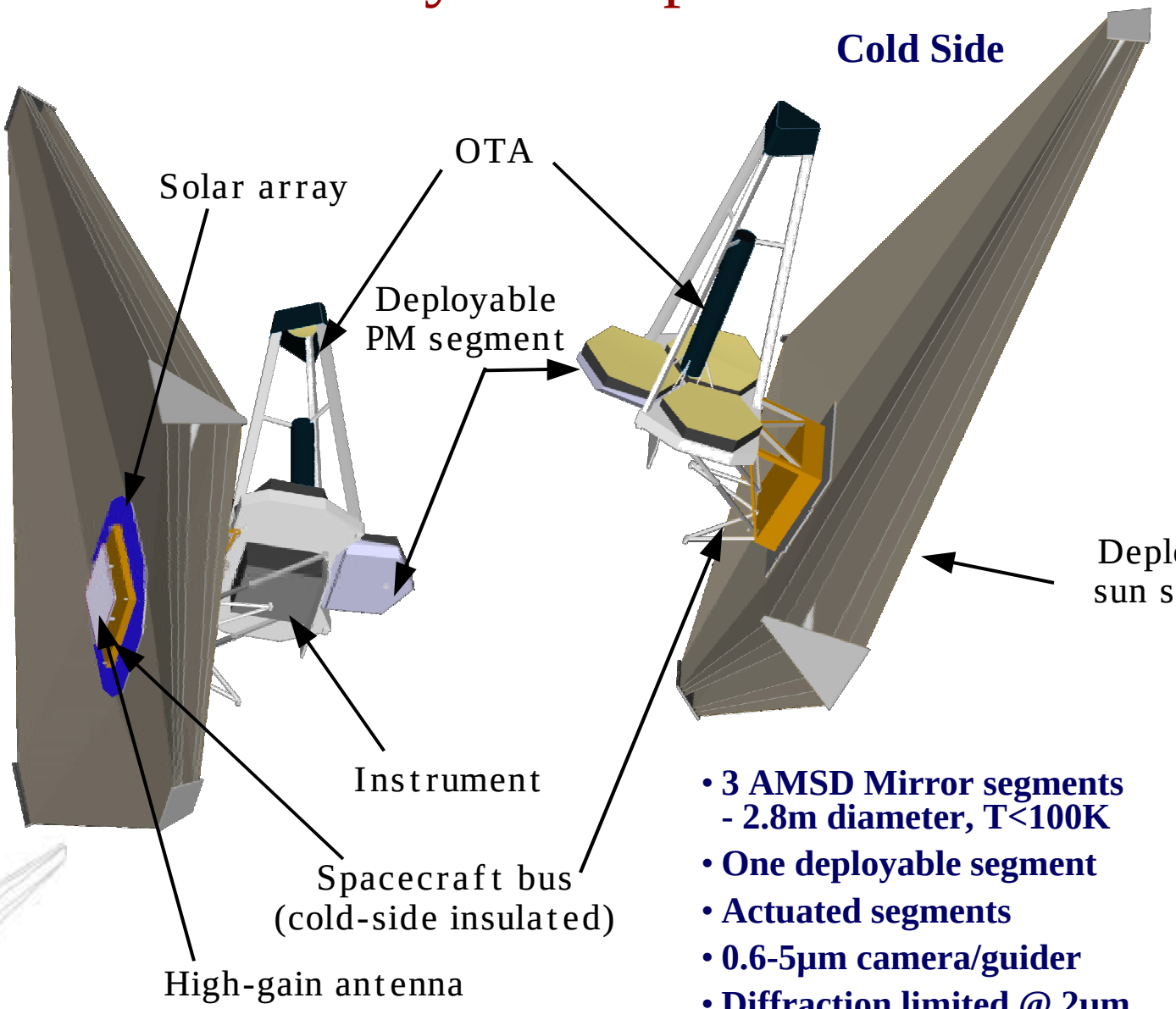
Nexus Observatory Concept



- **3 AMSD Mirror segments - 2.8m diameter, T<100K**
- **One deployable segment**
- **Actuated segments**
- **0.6-5µm camera/guider**
- **Diffraction limited @ 2µm**
- **Image based WFS**

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ISIM is the Payload of NGST

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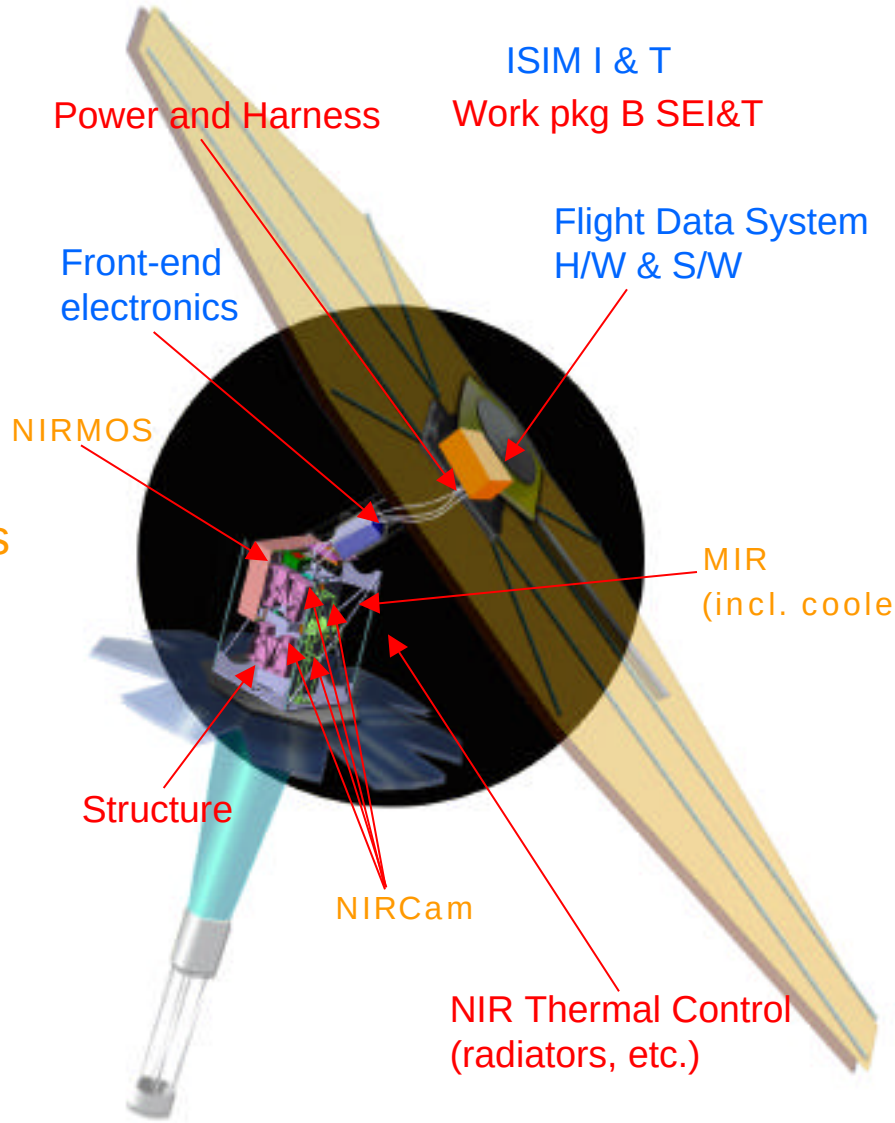


Instruments

Infrastructure

work pkg “A”

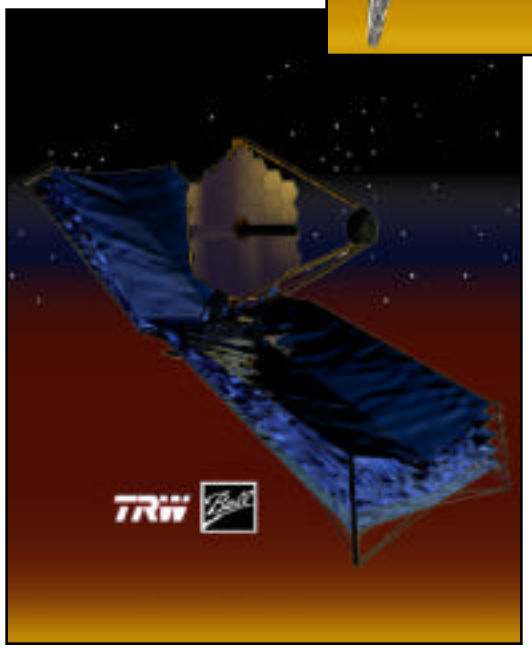
work pkg “B”

Data System GSE
for prime and each SI

Opto-mech-power
simulator GSE
for each SI

Major Accomplishments

- Contracted with TRW and Lockheed for Phase 1 Studies
  - Blue Dot Consortium was debriefed
- Awarded AMSD contracts to Ball, Raytheon, and Kodak
- Completion of the Ball SBMD mirror technology program
  - NMSD/COI mirror fab complete and mirror is in test
- ASWG and astronomical community consented to a preferred, prioritized instrument suite



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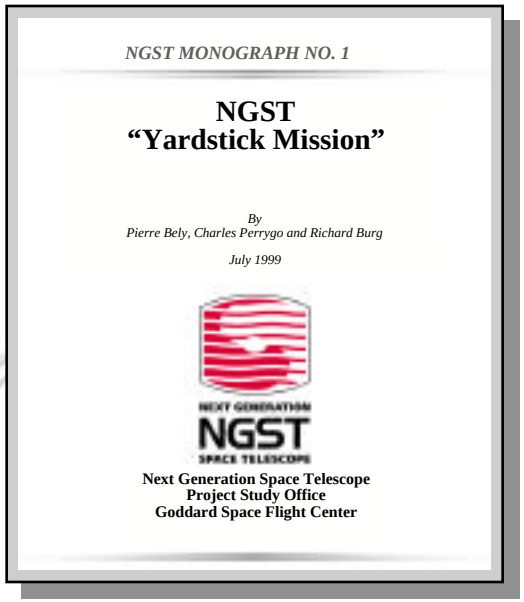
NGST Monograph Series

- Details of Government Team "Yardstick" NGST
  - Documents design philosophy/decisions
  - Transitions team role from leading to collaborating with Primes
- Similar to Keck Monograph Series
- Available online
  - http://www.ngst.nasa.gov/project/text/monographs.html



9 volumes

1. General Design Overview
2. Stray Light Analysis
3. Implications of MIR Capability
4. I & T Strawman Plan
5. System Requirements
6. Performance Analysis
7. Optical Quality Guidelines
8. Radiation Environment for NGST
9. Optical System Testing Strawman Plan

Next Generation Space Telescope
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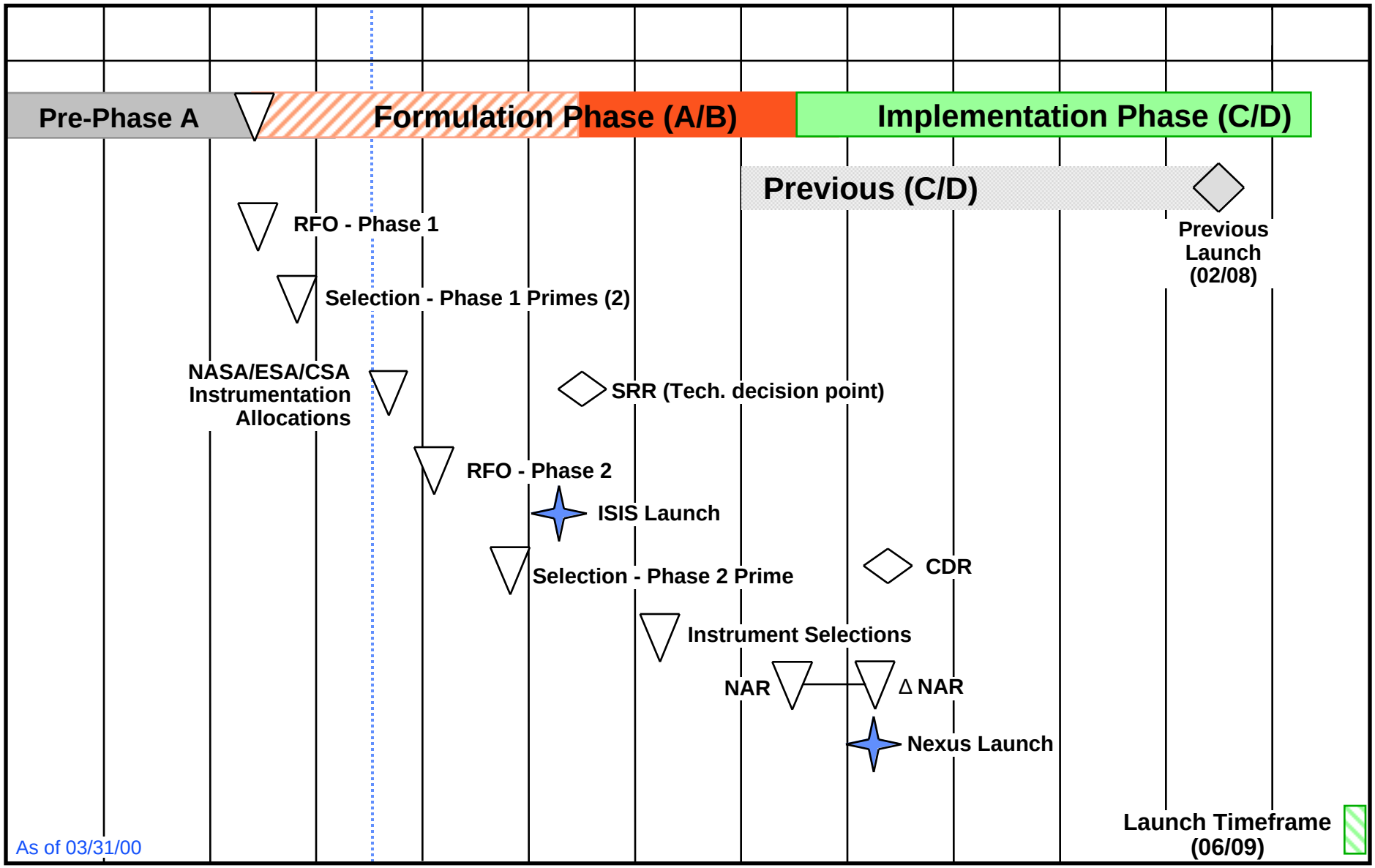
NGST Top Level Observatory Schedule



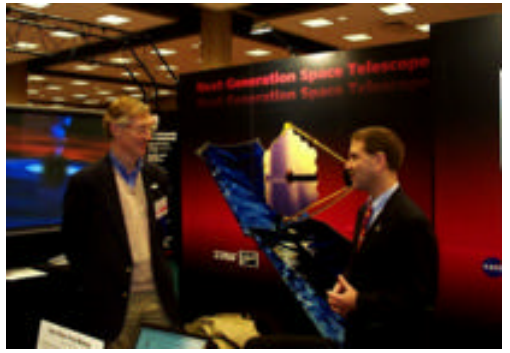
Launch Replanned for 2009 Because:

- Technology maturation rates slower than expected
  - Mirrors
  - Detectors
- Budget profile did not support instrument technology development
  - Multi-Object Spectrograph aperture selector devices
  - Cryocoolers
- Nexus pathfinder flight never properly phased with the AMSD program
  - AMSD pilot line
  - Full scale segment EMU
- Phase C/D duration, particularly I & T aspects, too aggressive at 54 months
- Overall, too success-oriented (no slack)

NGST Outreach

- Science Meetings
  - Atlanta AAS Instrument Capabilities presentation (1/00)
  - Detector Workshop (4/99)
- Hyannis Meeting (9/99)
  - ~250 participants from industry & academia
  - Proceedings published this summer by ASP
  - Final tech infusion meeting for NGST
- NGST.Site development begun
  - Public Outreach website similar to HST.Site

Atlanta AAS



Hyannis meeting

Next Generation Space Telescope

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Report Card for Last Year – Accomplishment Metrics

Last Year's Goals	Status to Date	Comments
• **Technology Development Milestones**		
- Cryogenic Actuator Prototype	- 3 prototypes successfully demonstrated adequate cryogenic performance	- All 3 prototypes will be manufactured for use in NMSD, AMSD mirrors
- DCATT Phase 1 Testbed	- Faulty mirror mount assembly precluded timely convergence of final figuring and polishing of the 1 meter segmented aluminum overcoated with Nickel primary mirror. Phase 1 was terminated. Work continues on the highly successful Phase 0 hardware	- Mirror mount was retrofitted with supports that permitted polishing to resume. Current OPD is 7λ, and convergence is 0.7λ likely by June '00
- NRA #2 Awards	- NRA #2 proposal received on May 5, selection in June, 2000	
- Technology Readiness Monograph	- Astronomical Society of the Pacific, volume 207, " NGST Science and Technology Exposition"	- Publication date is summer, 2000
- Advanced Mirror Systems Demonstrator	- Phase 1 complete. Phase 2 downselect complete, 3 firms selected	- Four prototype NGST active optics to be complete in summer, 2002

Report Card for Last Year – Accomplishment Metrics (cont'd)

Last Year's Goals	Status to Date	Comments
• **Architecture Studies**		
- Phase 1 Studies	- 2 strong Phase A/B study contractors competing since July, 1999	- Phase 2 downselect in July '01
- NGST Monograph Series	- 9 monographs complete and in publication (online now)	- Complete documentation of the Yardstick studies of 1996-1998
- Operations Concept Study	- ST ScI has released monographs on an NGST operations concept and an analysis of the cost of multiple instrument modes	- Monographs are on the Web
- International Allocation Process	- Tripartite planning on a Paris-May 25 agreement between Weiler/Bonnet	- Details to be worked out by March, 2001

Goals for the Next Year

- Programmatic
  1. Phase 2 Downselect
  2. Awards for NRA 2 for Instrument Technology
- Technology
  1. Advanced Mirror Systems Demonstrator (AMSD) Phase 2
  2. NGST Mirror Systems Demonstrator (NMSD) Phase 2 testing complete
  3. Focal Plane Development – SCA
  4. Wavefront Sensing & Control Testbeds Completion
- Science
  1. Revitalize Science advocacy group (ISWG)
- Systems Studies
  1. ISIM Delta Formulation Studies/Cost Estimates
  2. OTA Cost Model Development
  3. Cryocooler vs. Cryostat Trade Study
  4. International Agreements and Phase A/B Studies
- Pathfinder Flights

  ISIS Flight Experiment

  Nexus: Formulation/early Implementation

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Three Points to Remember about NGST

- Astronomical community has agreed to a limited set of highly focused science instrument capabilities
- Progress along technology roadmap compatible with successful demonstration by Non-advocate Review
- Successful rephasing of funds enables Nexus program to create dollar-for-dollar savings opportunities in NGST phase C/D costs

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